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*XI. On the finite extent of the Atmosphere.* By WILLIAM  
HYDE WOLLASTON, M. D. V. P. R. S.

Read January 17, 1822.

THE passage of Venus very near the sun in superior conjunction in the month of May last, having presented an opportunity of examining whether any appearance of a solar atmosphere could be discerned, I am in hopes that the result of my endeavours, together with the views which induced me to undertake the inquiry, may be found deserving of a place in the Philosophical Transactions.

If we attempt to estimate the probable height to which the earth's atmosphere extends, no phenomenon caused by its refractive power in directions at which we can view it, or by reflection from vapours that are suspended in it, will enable us to decide this question.

From the law of its elasticity, which prevails within certain limits, we know the degrees of rarity corresponding to different elevations from the earth's surface; and if we admit that air has been rarefied so as to sustain only  $\frac{1}{100}$  of an inch barometrical pressure, and that this measure has afforded a true estimate of its rarity, we should infer from the law, that it extends to the height of forty miles, with properties yet unimpaired by extreme rarefaction. Beyond this limit we are left to conjectures founded on the supposed divisibility of matter: and if this be infinite, so also must be the extent of

our atmosphere. For, if the density be throughout as the compressing force, then must a stratum of given thickness at every height be compressed by a superincumbent atmosphere, bearing a constant ratio to its own weight, whatever be its distance from the earth. But if air consist of any ultimate particles no longer divisible, then must expansion of the medium composed of them cease at that distance, where the force of gravity downwards upon a single particle is equal to the resistance arising from the repulsive force of the medium.

On the latter supposition of limited divisibility, the atmosphere which surrounds us will be conceived to be a medium of finite extent, and may be peculiar to our planet, since its properties would afford no ground to presume that similar matter exists in any other planet. But if we adopt the hypothesis of unlimited expansion, we must conceive the same kind of matter to pervade all space, where it would not be in equilibrio, unless the sun, the moon, and all the planets possess their respective shares of it condensed around them, in degrees dependent on the force of their respective attractions, excepting in those instances where the tendency to accumulate may be counteracted by the interference of other kinds of matter, or of other powers of which we have no experience, and concerning which we cannot expect to reason correctly.

Now, though we have not the means of ascertaining the extent of our own atmosphere, those of other planetary bodies are nevertheless objects for astronomical investigation; and it may be deserving of consideration, whether, in any instance, a deficiency of such matter can be proved, and whe-

ther, from this source, any conclusive argument can be drawn in favour of ultimate atoms of matter in general. For, since the law of definite proportions discovered by chemists is the same for all kinds of matter, whether solid, or fluid, or elastic, if it can be ascertained that any one body consists of particles no longer divisible, we then can scarcely doubt that all other bodies are similarly constituted; and we may without hesitation conclude that those equivalent quantities, which we have learned to appreciate by proportionate numbers, do really express the relative weights of elementary atoms, the ultimate objects of chemical research.

These reflections were originally suggested by hearing an opinion hazarded without due consideration, that the non-existence of perceptible atmosphere around the moon, might be regarded as conclusive against the indefinite divisibility of matter. There was, however, an oversight in this inference, as the quantity of such matter, which the moon would retain around her, could not possibly be perceived by the utmost power of any instruments hitherto invented for astronomical purposes. For, since the density of an atmosphere of infinite divisibility at her surface would depend on the force of her gravitation at that point, it would not be greater than that of our atmosphere is where the earth's attraction is equal to that of the moon at her surface. At this height, which by a simple computation is about 5000 miles from the earth's surface, we obviously can have no perceptible atmosphere, and consequently, should not expect to discern an atmosphere of similar rarity around the moon.

It is manifestly in the opposite direction that we are to look for information. We should examine first that body

which has the greatest power, and see whether even there the non-appearance of those phenomena which might be expected from such an atmosphere, will warrant the inference that our own is confined to this one planet by the limit set to its divisibility.

By converse of the same rule which gives an estimate of extreme rarity at the moon's surface, we may form a conception at what distance round the sun refraction from such a cause should be perceived. If we calculate at what apparent distance from the body of the sun his force is equal to that of gravity at the surface of the earth, it is there that his power would be sufficient to accumulate (from an infinitely divisible medium filling all space) an atmosphere\* fully equal in density to our own, and consequently producing a refraction of more than one degree, in the passage of rays obliquely through it.

If the mass of the sun be considered as 330.000 times that of the earth, the distance at which his force is equal to gravity will be  $\sqrt{330.000}$ , or about 575 times the earth's radius; and if his radius be 111,5 times that of the earth, then this distance will be  $\frac{575}{111,5}$  or 5.15 times the sun's radius; and  $15' 49'' \times 5,15 = 1^\circ 21' 29''$ , will be the apparent distance from the sun's centre on the 23d of May, when the following observations were made.

What deduction should be allowed for the effect of heat,

\* Such an atmosphere would, in fact, be of greater density on account of the far greater extent of the medium affected by the solar attraction, although of extreme rarity; but the addition derived from this source, may be disregarded in the present estimate, without prejudice to the argument, which will not be found to turn upon any minute difference.

it may be time to consider when we have learned the amount of apparent refraction at some given distance; and we may then begin to conjecture, whether heat can counteract the increase of density that would occur in the approach of only  $\frac{1}{10}$  of a second towards his centre.\*

As I had not any instrument in my possession that I considered properly adapted for the purpose, I requested the assistance of several astronomical friends in watching the progress of Venus to the sun for some days preceding superior conjunction, and in recovering sight of her afterwards. But neither the Astronomer Royal at Greenwich, nor Professor BRINKLEY of Dublin, nor Mr. SOUTH, with the admirable instruments they possess, were able to make any observation within the time required, not being furnished with the peculiar means adapted to this inquiry.

Captain KATER, however, who entered fully into my views, and engaged in the prosecution of them with all the ardour necessary for success, by using a reflecting telescope, was able to furnish me with a valuable set of observations,  $3\frac{1}{2}$  days preceding conjunction, which, together with those in which I had the good fortune to succeed at nearly an equal interval subsequent to the passage, afford data quite sufficient to show, that no refraction is perceptible at the period

\* If we attempt to reason upon what would be the progressive condensation of such an atmosphere downwards towards the surface of the sun, we are soon stopped by the limit of our experience as to the degree of condensation of which the atmosphere is susceptible. If we could suppose the common law of condensation to extend as far as forty-six miles in depth, the density corresponding to it, would be about equal to that of quicksilver, from whence a refraction would occur exceeding all bounds of reasonable calculation. A space of forty-six miles at the distance of the sun from us, would subtend about  $\frac{1}{10}$  of a second.

of our observations; and these come far within the specific distance above estimated.

A selection from the series given to me by Captain KATER is contained in the following table:

	h. m. s.	Diff. R. A.	Diff. calc.
		m. s.	from N. Alm. m. s.
May 18	2 40 25	4 25.6	...
	21 30 50	3 43.1	...
	23 27 58	3 38.8	...
	19 0 0	...	3 37
May 18	2 44 33	45 56	Diff. Decl.
	23 19 40	40 57	
	19 . . .	...	40 36

It is evident, that in these observations the differences between the observed and calculated places of the planet, are not such as to indicate a refraction that can be relied on.

My own observations were very few in number, and not to be compared to the former in precision; but they are necessary to supply a deficiency when Captain KATER was at a distance from his instruments, and could make no observation.

On the 26th, between XI. 20 and XI. 30 I had three comparative observations, the best of which gave me the passage of Venus  $3^m\ 55^s$  after the sun. The mean of two others being  $3^m\ 49^s$ . I consider the result as on the 25th,  $23^h\ 24^m$ . Diff. R. A.  $3^m\ 52^s$ .

The nearest second to be inferred from the Nautical Almanac for this time being  $3^m\ 53^s$  after the sun, it is evident that no perceptible refraction occurred at this time.

From the observations of Captain KATER, no retardation of

the motion of Venus can be perceived in her progress toward the sun, as would occur from increasing refraction; and by comparison of her motion in the interval between his last observation and my own, with her change of place for the same interval given in the Nautical Almanac, there seems no ground whatever to suppose that her apparent position has been in the least affected by refraction through a solar atmosphere, although the distance at the time of Captain KATER's last observation was but  $65' 50''$  from the sun's centre, and at the time of my own only  $53' 15''$ .

Although these distances appear small, I find that Venus has been seen at a still less distance by Mons. VIDAL of Montpellier in 1805.\* On the 30th of May, he observed Venus  $3^m 16'$  after the sun, when their difference of declination was not more than  $1'$ , so that her distance from the centre was about 46 minutes of space. Since his observations also accord with the calculated places of Venus, they might have superseded the necessity of fresh observations, if I had been duly aware of the inference to be drawn from them.

The same skilful observer has also recorded an observation of Mercury on the 31st of March of the same year, when he was seen at about  $65'$  from the sun's centre.

If I were to describe the little telescope with which my observations were made, without taking due care to explain the precautions adopted, and the grounds of their efficacy, it might perhaps be scarcely credible, that with an object glass less than one inch in aperture, having a focal length of only seven inches, I could discern an object not to be seen by telescopes of four and five inches aperture. We know, how-

\* Conn. des Tems. 1808.

ever, that this small aperture is abundantly sufficient for viewing Venus at a distance from the sun; and, since the principal obstruction to seeing her nearer (when the atmosphere is clear), arises from the glare of false light upon the object-glass, the success of the observation depends entirely on having an effectual screen for the whole object-glass, which is obviously far more easy to accomplish in the smaller telescope.

Since the screen which I employed was about six feet distant from my object-glass, a similar protection for an aperture of five inches would have required to be at the distance of thirty feet, to obviate equally the interference of the sun's light at the same period; but this is a provision with which regular observatories are not furnished for the common purposes of astronomy.

As I hope at some future time to avail myself of a larger aperture for such observations, without the necessity of mounting a more distant screen, it may be desirable that I should suggest to others the means by which this may be effected, if they think the question of a solar atmosphere worthy of farther investigation.

If an object-glass of four inches aperture be covered, so as to expose only a vertical slit of its surface one inch in width, the surface of glass to be so used is about five times as large as the circular aperture one inch in diameter, and yet will be as completely shaded by a vertical screen at any given distance: and an interval of only five feet, might allow a star or planet to be seen within a degree of the sun's disc.

When the sun and planet have the same declination, the vertical position of the slit is manifestly the most advantage-

ous that could be chosen on the meridian; but, for the purpose of seeing to the greatest advantage when the line of the centres is inclined to the horizon, it would be requisite to have the power of turning the slit and screen together at right angles to any line of direction of the centres.

The only fixed star sufficiently near to the ecliptic, and bright enough to give any prospect of its being seen near the sun, is Regulus, which passes between the 20th and 21st of August; but I have not yet had an opportunity of ascertaining within what distance from the sun this star can be discerned.

In the foregoing remarks, I have perhaps dwelt more upon the consideration of the solar atmosphere, than may seem necessary to those who have considered the common phenomena observable in the occultations of Jupiter's satellites by the body of the planet. Their approach, instead of being retarded by refraction, is regular, till they appear in actual contact; showing that there is not that extent of atmosphere which Jupiter should attract to himself from an infinitely divisible medium filling space.

Since the mass of Jupiter is full 309 times that of the earth, the distance at which his attraction is equal to gravity must be as  $\sqrt{309}$ , or about 17.6 times the earth's radius. And since his diameter is nearly eleven times greater than that of the earth,  $\frac{17.6}{11} = 1.6$  times his own radius will be the distance from his centre, at which an atmosphere equal to our own should occasion a refraction exceeding one degree. To the fourth satellite this distance would subtend an angle of about  $3^{\circ} 37'$ , so that an increase of density to  $3\frac{1}{2}$  times our common

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atmosphere, would be more than sufficient to render the fourth satellite visible to us when behind the centre of the planet, and consequently to make it appear on both (or all) sides at the same time.

The space of about six miles in depth, within which this increase of density would take place, according to known laws of barometric pressure, would not subtend to our eye so much as  $\frac{1}{300}$  of a second, a quantity not to be regarded in an estimate, where so much latitude has been allowed for all imaginable sources of error.

Now though, with reference to the solar atmosphere, some degree of doubt may be entertained in consequence of the possible effects of heat which cannot be appreciated, it is evident that no error from this source can be apprehended in regard to Jupiter; and as this planet certainly has not its due share of an infinitely divisible atmosphere, the universal prevalence of such a medium cannot be maintained; while, on the contrary, all the phenomena accord entirely with the supposition that the earth's atmosphere is of finite extent, limited by the weight of ultimate atoms of definite magnitude no longer divisible by repulsion of their parts.